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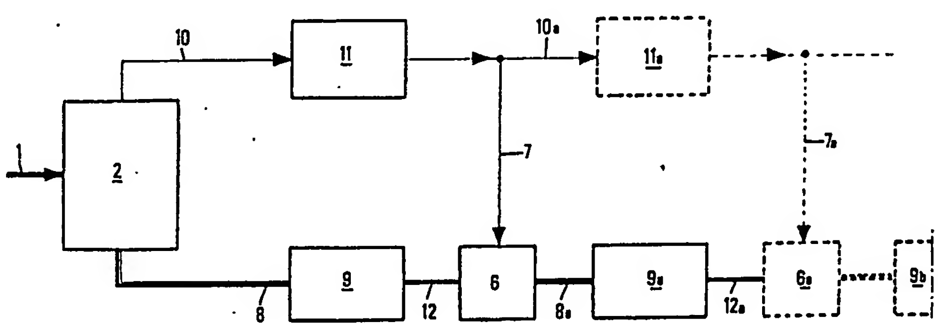
(54) Methods of and apparatus for conveying diphasic fluids through pipes

(57) To convey a diphasic fluid of high gas/liquid volumetric ratio, free gas content is separated by means 2 from the initial diphasic fluid, and pressure of the separated fluid and that of the residual gas are separately increased by pressure means 9 and 11 respectively to the same value and at least a fraction of the residual gas is subsequently mixed in mixing means 6 to this fluid to obtain a new fluid of reduced free gas content. These steps may be repeated by way of means 9*a*, 11*a*, 6*a* until the whole of the gaseous phase is dissolved in the liquid which can then be conveyed through a pipe.

FIG.1



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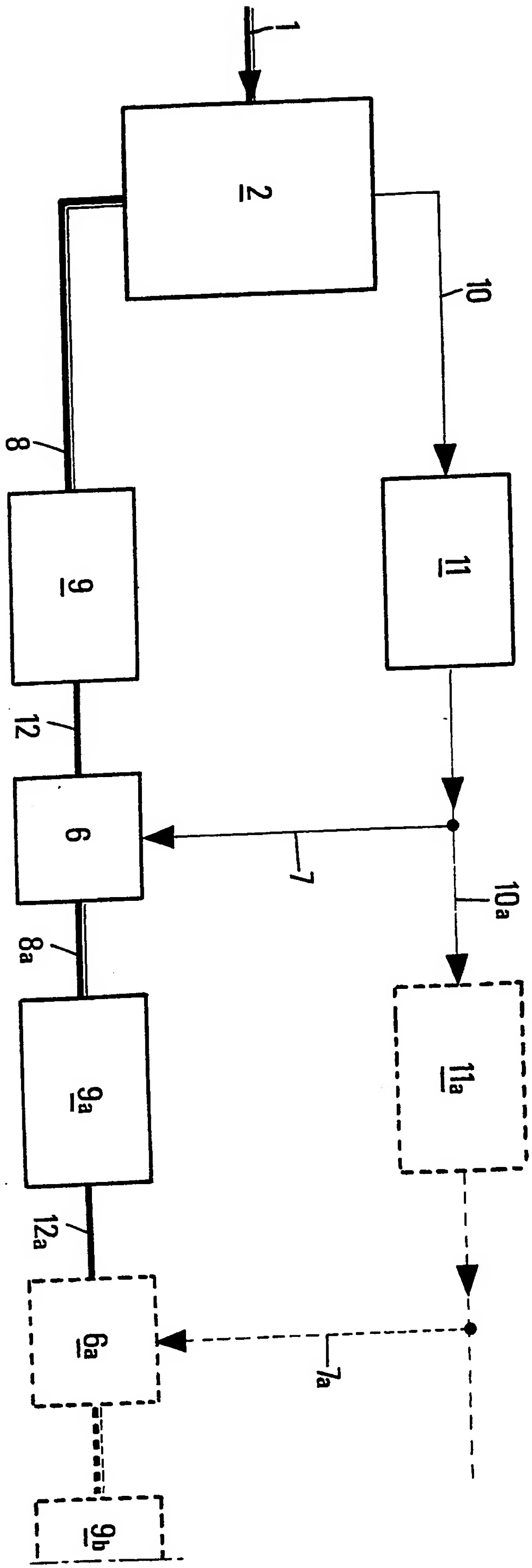
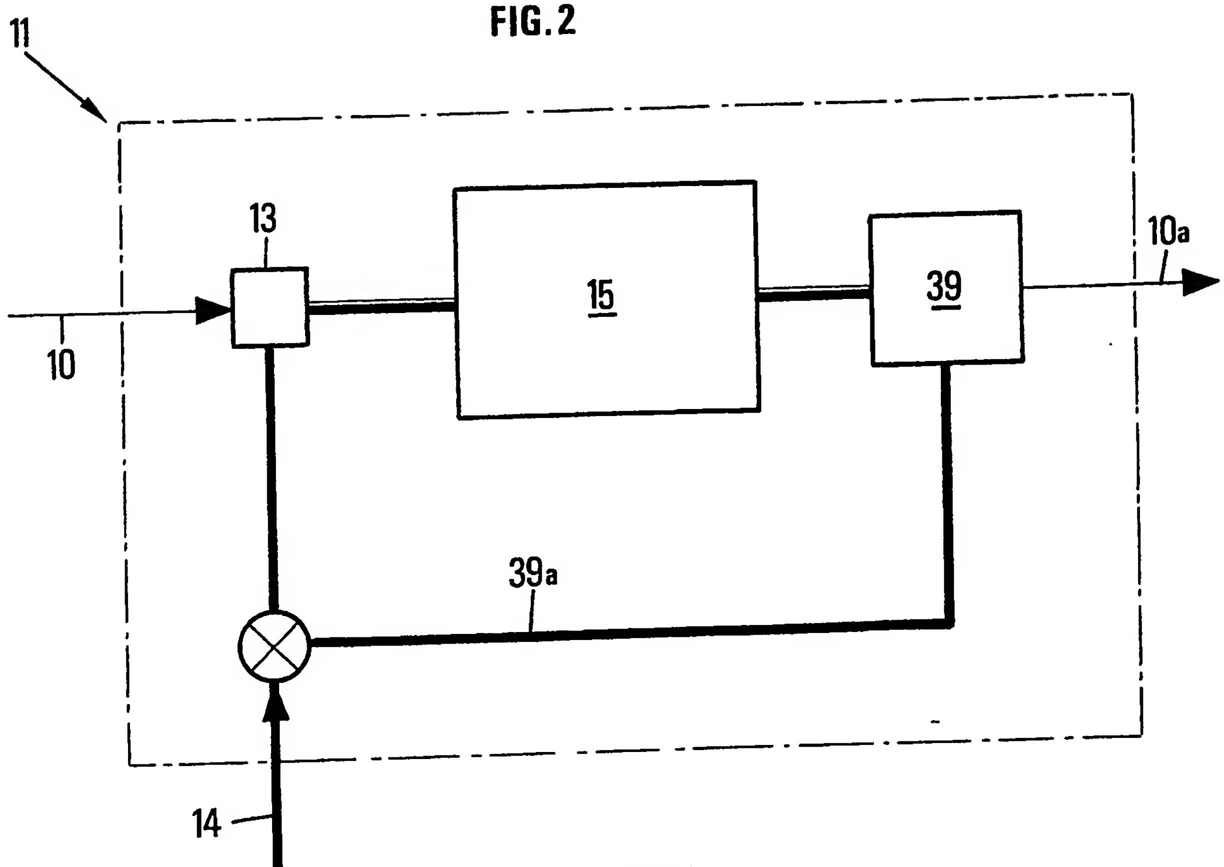


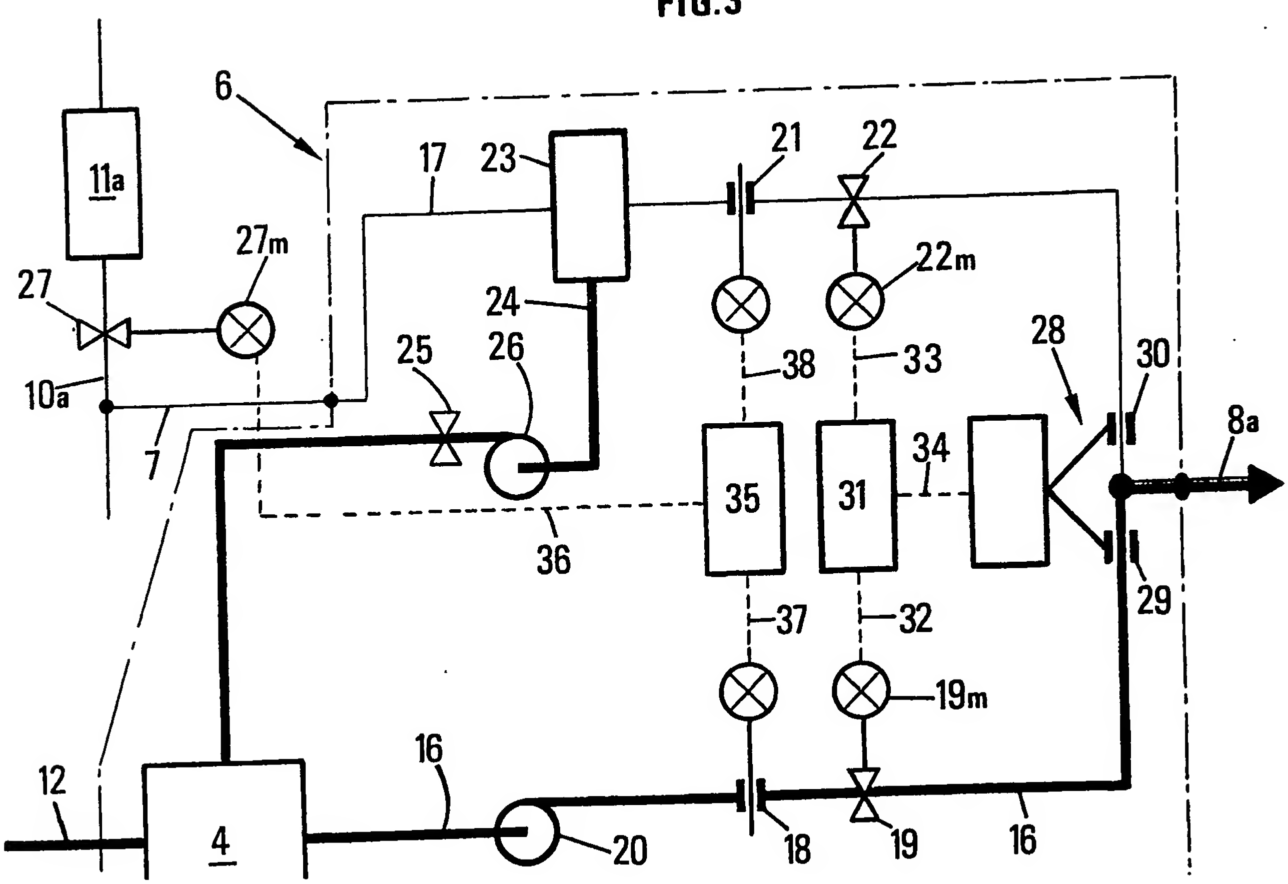
FIG.1

FIG.2



11
13
15
39
10
10a
39a
14

FIG.3



6
11a
17
23
21
22
27m
27
22m
24
25
26
38
33
28
30
10a
8a
7
35
31
34
36
29
37
32
19m
16
12
4
20
18
19
16

FIG.4

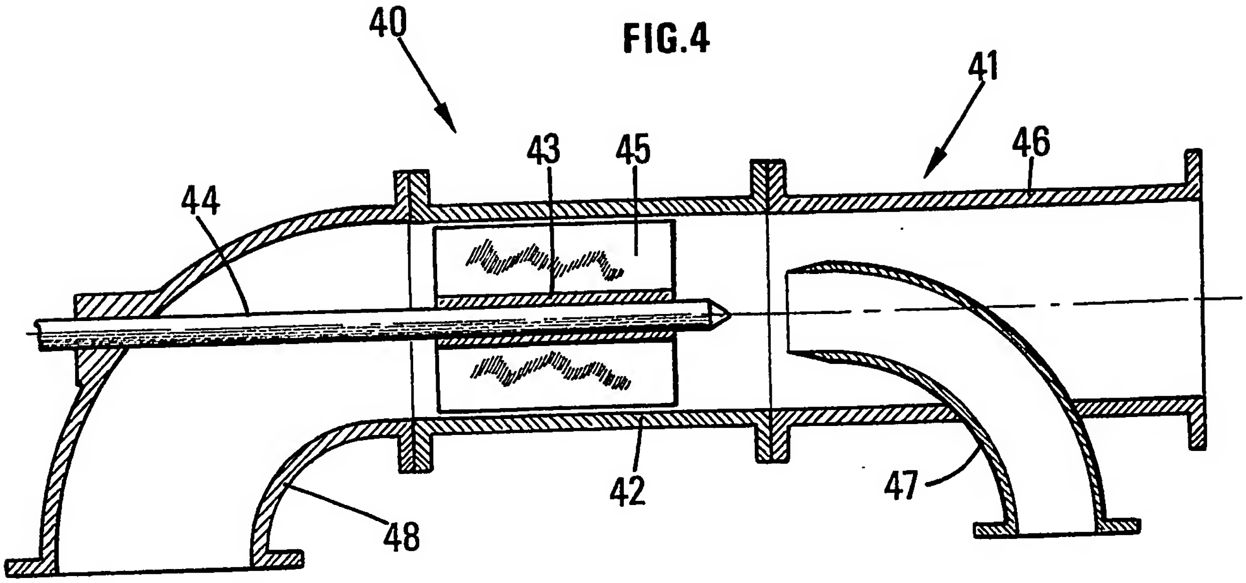


FIG.5

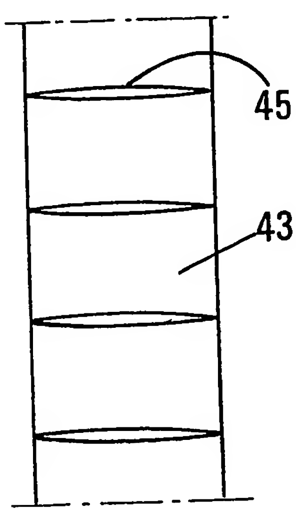


FIG.6

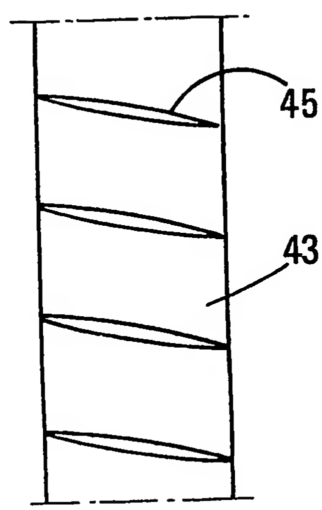


FIG.7

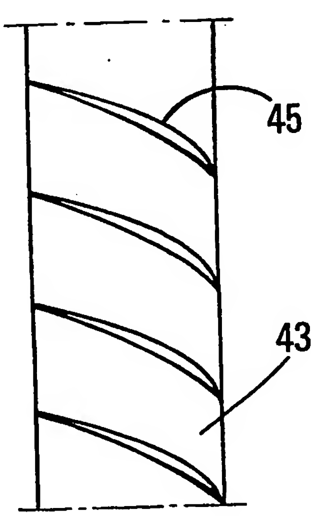
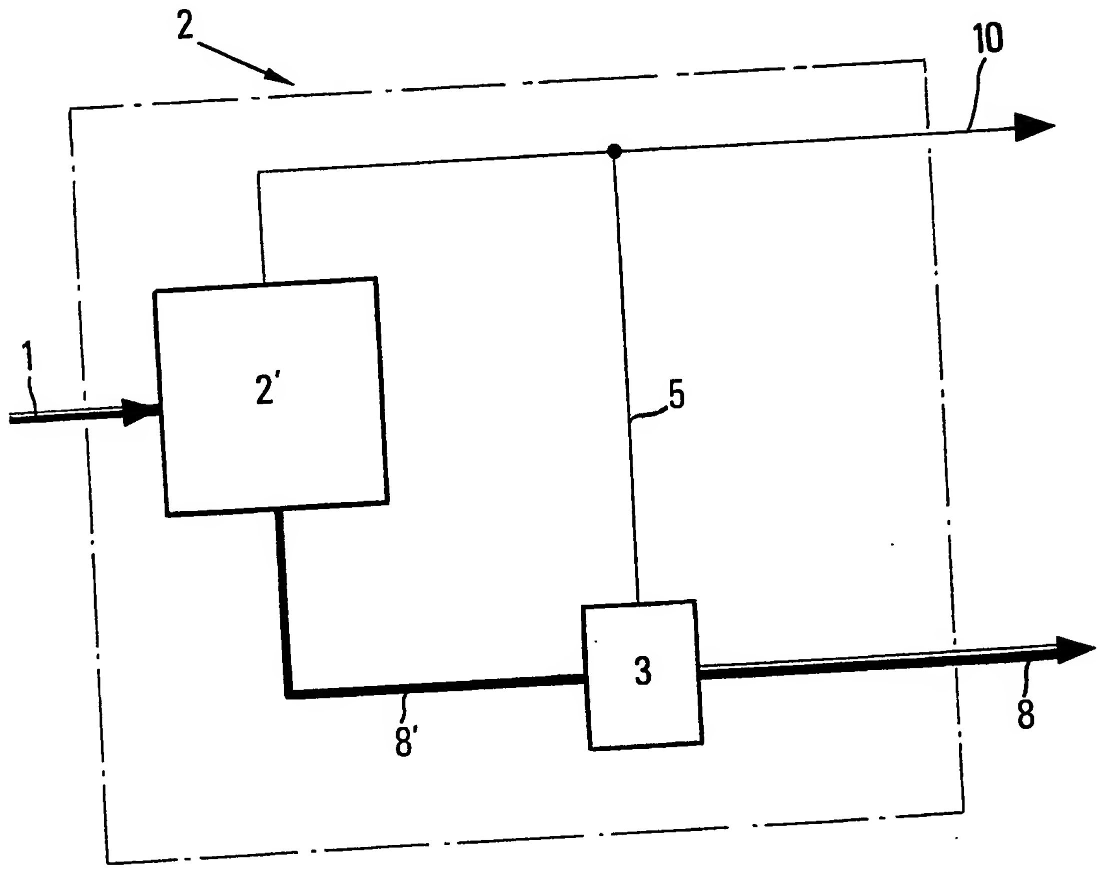


FIG.8



SPECIFICATION

Methods of and apparatus for conveying diphasic fluids through pipes

This invention relates to methods of and apparatus for conveying diphasic fluids through pipes.

In the following, reference is made, by way of non-limitative example, to the application of the invention to the complete recovery of petroleum effluents from oil producing fields.

Petroleum effluents from oil producing fields often comprise a liquid and a gas phase. When the gas content reaches 10 to 20% of the liquid content, which corresponds to a high volumetric gas/oil ratio, it is not possible to increase the pressure of the gas-liquid mixture with presently available pumping equipment and it becomes necessary to separate the liquid phase from the gas phase and to process them separately.

Such separation is achieved in one or more chambers by progressively reducing the pressure of the gas-liquid mixture to atmospheric pressure. Pumps are used to separately increase the liquid pressure to force it into a pipe or pipes provided therefor. The gas phase, which is separately processed, is either burnt in flares, i.e. without energy recovery, or sometimes used to produce a part of the power required for actuating the oil field equipment or reinjected into the oil-containing geological formations so as to increase the efficiency of oil recovery from these formations.

The gas phase is rarely liquified or conveyed through a separate line, since this would require a very high capital investment which, up to now, appear to provide little or no likelihood of profit.

Not only is the gas which is simultaneously produced with the liquid phase practically never recovered, but separation of the gas and liquid phases requires bulky equipment, which is a serious drawback in the case of offshore oil producing fields and requires a non-negligible power consumption for increasing again and the gas pressure which has been reduced during the gas-liquid separation.

An embodiment of the present invention described hereinbelow obviates or at least reduces these drawbacks by providing a method permitting the recovery of the greatest part of the petroleum effluents from an oil field, and the conveyance of both gas and liquid phases through one and the same pipe.

According to a first aspect of the invention there is provided a method of simultaneously conveying in the same pipe the liquid and gas components of a diphasic flow of high gas/liquid volumetric ratio, comprising separating the diphasic flow to form a fluid of reduced free gas content and a residual gas, said fluid comprising at least the liquid contained in the diphasic flow, and carrying out at least once the following series of steps, to obtain a fluid of limited free gas content, lower than a preselected value, such fluid being introduced into said conveying pipe, said series of steps comprising:

b) simultaneously increasing to the same value the pressure of the residual gas, and

c) producing a new fluid of reduced free gas content by admixing said fluid of reduced free gas content with said residual gas.

According to a second aspect of the invention there is provided apparatus for simultaneously conveying in the same pipe the components of a diphasic flow, the apparatus comprising a separator operative to deliver through a first orifice at least the whole amount of the liquid contained in said diphasic flow, and through a second orifice at least a fraction of the gas contained in said flow, and at least one fluid processing unit comprising first pumping means for increasing the pressure of fluid flowing therethrough, said first pumping means having an inlet orifice communicating with said first orifice of the separator, second pumping means for increasing gas pressure, said second pumping means having an inlet orifice communicating with said second orifice of the separator, and mixing means having inlet orifices connected to receive the fluid and gas delivered by said first and second pumping means respectively, the mixing means being operative to mix under substantially constant pressure at least a fraction of the gas with the fluid delivered by said first pumping means.

Apparatus embodying the invention described hereinbelow has the advantage of being compact, which facilitates its application to offshore oil production equipment.

The invention will now be further described, by way of example, with reference to the accompanying drawings, wherein:

Figure 1 diagrammatically illustrates apparatus for carrying out a method embodying the invention;

Figure 2 shows an embodiment of a device used in the apparatus of Figure 1 for increasing gas pressure;

Figure 3 illustrate a possible embodiment of a mixing element of the apparatus of Figure 1; and

Figures 4 to 8 illustrate embodiments of a gas-liquid separator of the apparatus of Figure 1.

In Figure 1, reference numeral 1 designates a pipe fed with a fraction of or with the whole of the oil effluent, under pressure, from an oil producing field, the effluent comprising a liquid and a gas phase having a volumetric gas/liquid ratio such that its pressure cannot be increased by using presently available pumping means.

The effluent is introduced into a gas-liquid separating element or separator 2 which is operative to separate the gas and liquid components of the effluent, preferably without any substantial pressure decrease. The separating element 2 delivers into a pipe 8 at least the liquid fraction of the petroleum effluent. More specifically, the separating element 2 is operative to deliver to the pipe 8 a diphasic fluid whose gas/liquid volumetric ratio is at most equal to the maximum value of the volumetric ratio of the diphasic fluid mixture which can be processed by a pumping element 9 having

to increase the pressure of the diphasic fluid and to reduce the value of the volumetric ratio of the diphasic fluid, preferably to zero, i.e. to a value at which the whole amount of the gas fed to the pumping element 9 is dissolved in the liquid phase.

The remaining fraction of the gas delivered by the separating element 2 is simultaneously transmitted through a pipe 10 to an element 11 capable of increasing the pressure of the gas to a value substantially equal to the pressure of the liquid delivered by the pumping element 9.

A fraction of the gas leaving the element 11 is supplied through a pipe 7 to a mixing element 6 which also receives from the pipe 12 the pressurised fluid delivered by the pumping element 9.

The mixing element 6 produces a diphasic fluid of a predetermined volumetric ratio, this fluid being transmitted to a pumping element 9*a* which is smaller to the pumping element 9 in that it increases the pressure of the diphasic fluid and reduces its gas/liquid volumetric ratio, preferably to zero.

If the whole amount of the gas delivered by the separation element 2 is not dissolved in the liquid, the residual gas amount is supplied through a pipe 10*a* to a pressure increasing element 11*a* and is thereafter admixed with the liquid delivered by the pumping element 9*a* in a mixing element 6*a* whose outlet orifice is connected to another pumping element 9*b*, etc.

When substantially all the gas is dissolved in the liquid the resulting mixture is introduced into a conveying pipe (not shown) to be delivered to a utilisation site, where vapourisation of the dissolved gas can be obtained by decompression followed by separation of the gas from the liquid.

It is thus apparent that, in the case of petroleum effluents, the above method permits recovery of the gaseous fraction of the effluents withouh requiring any additional conduit for conveying the gaseous fraction.

The pumping elements, such as those designated by reference 9, 9*a*, 9*b*, .., may be of any known type. However, for building a compact apparatus which requires a minimum number of pumping elements it is preferable to use helico-axial pumps of the type described in French Patent Specification No. 2 333 139, capable of increasing the pressure of diphasic fluids having a higher volumetric gas/liquid ratio than the diphasic fluids processed by conventional pumping means.

The elements such as 11, 11*a* .., for increasing the gas pressure may of the known type, for example, compressors, or alternatively of the type described in our copending UK Patent Application No. 7904995 (Publication No.).

Briefly, as shown in Figure 2, the element 11 (for example) comprises a mixer 13 which receives the gas from the pipe 10 and a sufficient amount of an auxiliary liquid which may be, for example, a fraction of the liquid delivered by the separating element 2 or which results from a chemical modification of the gas produced by the separating element 2, this auxiliary liquid being introduced at 14. The illustrated in Figure 4 of our above-mentioned copending UK Patent Application No. 7904995 (Publication No.), delivers a diphasic fluid feeding a suitable pumping element 15, which may, for example, be a helico-axial pump, as indicated above. Optionally, a separator 39, similar to the separator 2, will permit recovery of the auxiliary liquid which may be recycled into the mixer 13 through pipe 39*a*.

The mixing elements 6, 6*a*, . . . may be of any known suitable type. A non-limitative embodiment of the mixing element 6 (for example) is illustrated in Figure 3. This mixing element comprises pipes 16 and 17 which respectively connect the pipes 7 and 12 to the pipe 8.

In series with the pipe 16 are connected an element 18 for measuring the volume (or flow rate) of liquid flowing through the pipe 16, an element 19 creating an adjustable pressure drop, and (optionally) a pump 20 ensuring liquid circulation in the pipe 16 and a liquid buffer tank 4.

In series with the pipe 17 are connected an element 21 for measuring the volume (or flow rate) of gas flowing the the pipe 17, an element 22 creating an adjustable pressure drop, and (optionally) a drain tank 23 wherein the liquid fraction which might be contained in the gas flow can be recovered by gravity, the bottom of the tank 23 being connected to a drain pipe 24 provided with valve means 25 for partial or full closure of the pipe 24, and (optionally) with a pump 26. Adjustment of the degree of opening of the valve means 25 and control of operation of the pump 26 may be achieved automatically and sequentially, for example by a device (not shown) for sensing the liquid level in the tank 25. In the embodiment illustrated in Figure 3, the pipe 24 connects the drain tank 23 to the liquid buffer tank 4.

The mixing element 6 is also provided with means diagrammatically indicated at 28, comprising, for example, two pressure sensors 29 and 30 which measure the pressure in the pipes 16 and 17, respectively, immediately before their points of connection to the pipe 8*a*, the means 28 being operative to deliver a signal representing the difference of the respective pressures measured by the sensors 29 and 30.

The elements 19 and 22 for creating pressure drops in the fluid are automatically set to the desired position by motor means diagrammatically shown at 19*m* and 22*m*. The motor means 19*m* and 22*m* are energised by a control circuit or element 31 to which they are connected by transmission lines 32 and 33 respectively, the control circuit being responsive to the signal delivered by the means 28 and transmitted thereto by a line 34.

The mixing element 6 also comprises an element 27 creating an adjustable pressure drop in the gas flowing through the pipe 10*a* and the element 11*a* operative to increase the gas pressure.

The element 27 creating a pressure drop is automatically set to the desired position by motor means 27*m* actuated by a control element 35 which transmits a control signal via a line 36 in relation to

and 21 and transmitted to the control element 35 via lines 37 and 38.

During operation, the liquid and gas are supplied to the mixing element 6 at substantially the same pressure P_E and the diphasic fluid is delivered to the pipe 8a at a pressure P_S which is generally slightly lower than P_E.

The means 28 delivers a signal representative of the difference between the respective pressures in the pipes 16 and 17, immediately before their points of connection to the pipe 8*a*. In dependence on this signal, the control element 31 actuates the motor means 19*m* and 22*m* which adjust the elements 19 and 22 creating pressure drops, so that the pressure difference measured by the means 28 is reduced and can be nullified.

Simultaneously, the flow rates (or volumes) of gas and liquid flowing through the pipes 16 and 17 are measured by the elements 18 and 21 respectively, which deliver signals representative of these flow rates which are transmitted to the control element 35.

The control element 35 generates a signal controlling the motor means 27*m* which adjusts the element 27 creating a pressure drop, so that the ratio of the gas flow rate to the liquid flow rate remains substantially constant at a preselected value substantially equal to the ratio of the gas to liquid volume which should be obtained for conveying the diphasic fluid through the pipe.

Thus, when the ratio of the signals produced by the elements 21 and 18 is greater than a predetermined value corresponding to the value of the gas to liquid volumetric ratio which should be obtained for conveying the diphasic fluid through the pipe 8*a*, the control element 35 reduces the value of the pressure drop at 27, thereby increasing the gas flow rate through the pipe 10*a* and consequently reducing the gas flow rate through the pipe 17.

On the other hand, when the ratio of the signals delivered by the elements 21 and 18 is lower than the preselected value, the control element 35 increases the pressure drop at 27, thus reducing the gas flow rate through the pipe 10a, and consequently increasing the gas flow rate in the pipe 17.

In other words, the mixing element 6 equalises the gas and liquid pressures before mixing by monitoring the values of the dynamic pressure drops in the gas and liquid flows in relation to the pressure difference between these respective flows, and also controls the gas flow rate in dependence on the gas to liquid volumetric ratio.

The measuring elements 18 and 21, which are for example flow-meters, the elements 19, 22 and 27 for creating pressure drops, which are for example adjustable diaphragms, and the pressure sensors 29 and 30 are well known to those of ordinary skill in the art and will therefore not be described here in detail; nor will the control elements 31 and 35.

The drain tank 23, in series with the pipe 17, makes it possible to recover by gravity the liquid fraction which may be contained in the gas flow.

The gas-liquid separator 2 shown in Figure 1 may be of any known type. Figure 4 shows, by way of 2, which essentially comprises an active element 40 capable of imparting a rotary movement to the fluid in a plane perpendicular to the direction of flow, and a distributing element 41 which separately delivers the gas and the liquid.

The active element 40 comprises a tubular body 42 housing a rotor 43 rotatable with the shaft 44 of a motor (not shown). The rotor 43 carries blades 45 which, as illustrated in Figures 5, 6 and 7 which represent developed views of the alternative forms of the rotor, maybe of plane configuration and extend radially (Figure 5), or inclined to the axis of rotation (Figure 6) or curved (Figure 7).

In the embodiments of Figures 6 and 7 the angle of inclination of the blades 45 to the axis of rotation of the rotor 43 is determined in relation to the axial rate of the flow and the running speed of the rotor 45.

Under the action of the centrifugal force developed by the rotation, the liquid and gas phase are separated, the gas phase being maintained near the flow axis, while the liquid phase, of higher density, is at a distance from the rotor axis.

The ends of the rotor 43 may optionally be streamlined to substantially avoid any disturbance in the flow.

Under these conditions, as shown in Figure 4, the distributing element 41 is formed from two tubes 46 and 47, the smaller (47) of these tubes collecting substantially only gas. The two tubes 46 and 47 are coaxial over a portion of their length and are respectively connected to the pipes 8 and 10 (Figure 1). The whole liquid phase is then collected at the outlet of tube 46, to which phase is optionally added the portion of gas phase which has not been collected by the tube 47.

The diphasic fluid is introduced into the assembly 40–41 by a connecting pipe 48 connected to the pipe 1.

Figure 8 diagrammatically illustrates another embodiment of the separating element 2 of Figure 1. This embodiment comprises a separator 2′ delivering the whole gas phase of the diphasic flow in the pipe 1 to the pipe 10, and the whole liquid phase to a pipe 8′. The pipe 8′ is connected to the pipe 8 through a mixer 3 which simultaneously receives the gas delivered by the separator 2′ and delivers a diphasic fluid of predetermined gas/liquid volumetric ratio.

Changes may be made to the above exemplary disclosure without departing from the scope of the present invention. For example, whereas the embodiment of the element 40 illustrated in Figure 4 comprises only one rotor, it is possible to use two distinct rotors rotated by two separate motors whose rotational speeds can be continuously varied.

Moreover, it is possible to use a separator 2 of any known type which delivers to the pipe 8 only the liquid phase of the flow from the pipe 1. The pumping element 9, which may then be of any known type, increases the pressure of the liquid which then becomes undersaturated with gas. A sufficient amount of gas is fed from the mixer 6 into

quid in the pipe 8*a*. A further pressure increase performed by the pump 9*a* causes under-saturation of the liquid wherein a further amount of gas can thus be dissolved. This fluid processing may be continued until complete dissolution of the gas in the liquid phase takes place.

CLAIMS

1. A method of simultaneously conveying in the same pipe the liquid and gas components of a diphasic flow of high gas/liquid volumetric ratio, comprising separating the diphasic flow to form a fluid of reduced free gas content and a residual gas, said fluid comprising at least the liquid contained in the diphasic flow, carrying out at least once the following series of steps, to obtain a fluid of limited free gas content, lower than a preselected value, such fluid being introduced into said conveying pipe, said series of steps comprising:

a) increasing the pressure of said fluid of reduced free gas content,

b) simultaneously increasing to the same value the pressure of the residual gas, and

c) producing a new fluid of reduced free gas content by admixing said fluid of reduced free gas content with said residual gas.

2. A method according to claim 1, wherein said fluid of reduced free gas content and said residual gas are produced without any substantial pressure reduction.

3. A method according to claim 1 or claim 2, employing pumping means capable of processing diphasic fluids whose gas/liquid volumetric ratio is at most equal to a limit value, wherein said fluid of limited free gas content has a gas/liquid volumetric ratio at most equal to said limit value.

4. A method according to claim 3, wherein said new fluid of reduced free gas content has a gas/liquid volumetric ratio at most equal to said limit value and wherein the pressure of said new fluid is increased before its introduction into said pipe.

5. Apparatus for simultaneously conveying in the same pipe the components of a diphasic flow, the apparatus comprising a separator operative to deliver through a first orifice at least the whole amount of the liquid contained in said diphasic flow, and through a second orifice at least a fraction of the gas contained in the said flow, and at least one fluid processing unit comprising first pumping means for increasing the pressure of fluid flowing therethrough, said first pumping means having an inlet orifice communicating with said first orifice of the separator, second pumping means for increasing gas pressure, said second pumping means having an inlet orifice communicating with said second orifice of the separator, and mixing means having inlet orifices connected to receive the fluid and gas delivered by said first and second pumping means respectively, the mixing means being operative to mix under substantially constant pressure at least a fraction of the gas with the fluid delivered by said first pumping means.

6. Apparatus according to claim 5, comprising a plurality of said fluid processing units connected in series.

7. Apparatus according to claim 5 or claim 6, wherein said first pumping means is capable of increasing the pressure of diphasic fluids whose gas/liquid volumetric ratio is at most equal to a limit value, and wherein said separator is operative to deliver through its first orifice a diphasic fluid whose gas/liquid volumetric ratio is at most equal to said limit value.

8. Apparatus according to claim 6, claim 6 or claim 7, wherein said mixing means comprise means to substantially equalise the pressures of the residual gas and of the fluid delivered by said first pumping means before mixing, and means for controlling the amount of mixed gas as a function of the amount of fluid, in dependence on the value of a gas/liquid volumetric ratio which must be obtained.

9. Apparatus according to any one of claims 5 to 8, wherein said second pumping means comprises means for producing a diphasic fluid by mixing the gas with an auxiliary liquid, means for pumping the resulting diphasic fluid, and a gas/liquid separator connected to receive the diphasic fluid after its pressure has been increased.

10. Apparatus according to claim 7, wherein the separator is operative to simultaneously deliver all the liquid through its first orifice and substantially all the gas of the processed diphasic fluid through its second orifice, and wherein mixing means are connected between said first orifice and the inlet orifice of said first pumping means to receive simultaneously gas from the second orifice of said separator, said mixing means being operative to produce a diphasic fluid whose gas/liquid volumetric ratio has a value at most equal to said limit value.

11. A method of simultaneously conveying in the same pipe the liquid and gas components of a diphasic flow of high gas/liquid volumetric ratio, the method being substantially as herein described with reference to Figures 1 to 4 and any one of Figures 5 to 7, or Figure 8, of the accompanying drawings.

12. Apparatus for simultaneously conveying in the same pipe the components of a diphasic flow, the apparatus being substantially as herein described with reference to Figures 1 to 4 and any one of Figures 5 to 7, or Figure 8, of the accompanying drawings.

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